

U.S. Department of Energy

HYDROGEN PROGRAM: FY2009 Budget Request Briefing

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**Energy Efficiency & Renewable Energy
Washington, DC**





INTRODUCTION: *FY2009 budget in brief*

The FY 2009 Budget Request:

Increases funding for:

- Hydrogen Storage R&D
- Fuel Cell Stack Component R&D
- Distributed Energy Fuel Cell Systems
- Basic Science

Moves/reduces funding for:

➤ Technology Validation; Safety, Codes & Standards; and Education

- *Moved to Vehicle Technologies to leverage synergies within fuel cell, plug-in hybrid, and biofuel vehicle validation efforts*
- *Funding for FCV Validation cut in half; impact on learning demo TBD*

➤ Renewable Hydrogen Production and Manufacturing R&D

- *Funding eliminated; not on critical path for 2015 technology readiness*
- *Hydrogen from natural gas available economically; Program has met critical path target of \$3.00/gge; still enables reduction in WTW CO₂ emissions*

Results:

- *FY 2009 budget request for EERE Hydrogen Program has been reduced*
- *A more balanced EERE portfolio of near-, mid-, and long-term solutions*



Hydrogen Fuel Initiative

President Bush committed **\$1.2 billion over 5 years (FY04 – FY08)** to accelerate R&D to enable technology readiness in 2015.

| Hydrogen Fuel Initiative Funding ¹ (\$ in millions) | | | | | |
|--|--------------------|--------------------|--------------------|--------------------|---------------------------|
| FY 2004 Approp. | FY 2005 Approp. | FY 2006 Approp. | FY 2007 Approp. | FY 2008 Approp. | TOTAL (FY04 – FY08) |
| 157 | 222 | 232 | 268 | 281 | 1,159 |

- The President's cumulative request of \$1.267 B (for FY04 – FY08) is consistent with the original commitment of \$1.2 B.

¹ Includes EERE, FE, NE, SC and Department of Transportation



Hydrogen Fuel Initiative Budget

FY 2004 – FY 2009

| | Funding (\$ in thousands) | | | | | |
|---|---------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | FY 2004 Approp. | FY 2005 Approp. | FY 2006 Approp. | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Request |
| HYDROGEN FUEL INITIATIVE | | | | | | |
| EERE Hydrogen | 144,881 | 166,772 | 153,451 | 189,511 | 211,062 | 177,713* |
| Fossil Energy (FE) | 4,879 | 16,518 | 21,036 | 21,513 | 21,773 | 11,430 |
| Nuclear Energy (NE) | 6,201 | 8,682 | 24,057 | 18,855 | 9,909 | 16,600 |
| Science (SC) | 0 | 29,183 | 32,500 | 36,388 | 36,388 | 60,400 |
| DOE Hydrogen TOTAL | 155,961 | 221,155 | 231,044 | 266,267 | 279,132 | 266,143 |
| Department of Transportation | 555 | 549 | 1,411 | 1,420 | 1,425 | 1,425 |
| Hydrogen Fuel Initiative TOTAL | 156,516 | 221,704 | 232,455 | 267,687 | 280,557 | 267,568 |

* includes \$146,213,000 for HFCIT and \$31,500,000 for Vehicle Technologies



EERE Hydrogen Program Budget

FY 2004 – FY 2009

| Activity | Funding (\$ in thousands) | | | | | |
|--------------------------------------|---------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | FY 2004 Approp. | FY 2005 Approp. | FY 2006 Approp. | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Request |
| Hydrogen Production & Delivery | 10,083 | 13,303 | 8,391 | 33,702 | 39,636 | 0 |
| Hydrogen Storage R&D | 13,628 | 22,418 | 26,040 | 33,728 | 43,501 | 59,200 |
| Fuel Cell Stack Component R&D | 24,551 | 31,702 | 30,710 | 37,100 | 43,600 | 62,700 |
| Technology Validation | 15,648 | 26,098 | 33,301 | 39,413 | 29,727 | 0* |
| Transportation Fuel Cell Systems | 7,317 | 7,300 | 1,050 | 7,324 | 7,927 | 6,600 |
| Distributed Energy Fuel Cell Systems | 7,249 | 6,753 | 939 | 7,257 | 7,630 | 10,000 |
| Fuel Processor R&D | 14,442 | 9,469 | 637 | 3,952 | 2,973 | 0 |
| Safety, Codes & Standards | 5,755 | 5,801 | 4,595 | 13,492 | 15,854 | 0* |
| Education | 2,417 | 0 | 481 | 1,978 | 3,865 | 0* |
| Systems Analysis | 1,429 | 3,157 | 4,787 | 9,637 | 11,395 | 7,713 |
| Manufacturing R&D | 0 | 0 | 0 | 1,928 | 4,954 | 0 |
| Technical/Program Mgt. Support | 395 | 535 | 0 | 0 | 0 | 0 |
| Congressionally Directed Activities | 41,967 | 40,236 | 42,520 | 0 | 0 | 0 |
| TOTAL | 144,881 | 166,772 | 153,451 | 189,511 | 211,062 | 146,213 |

* Transferred \$31.5M to Vehicle Technologies (\$15M Tech Val; \$12.5M SC&S; \$4M Education)

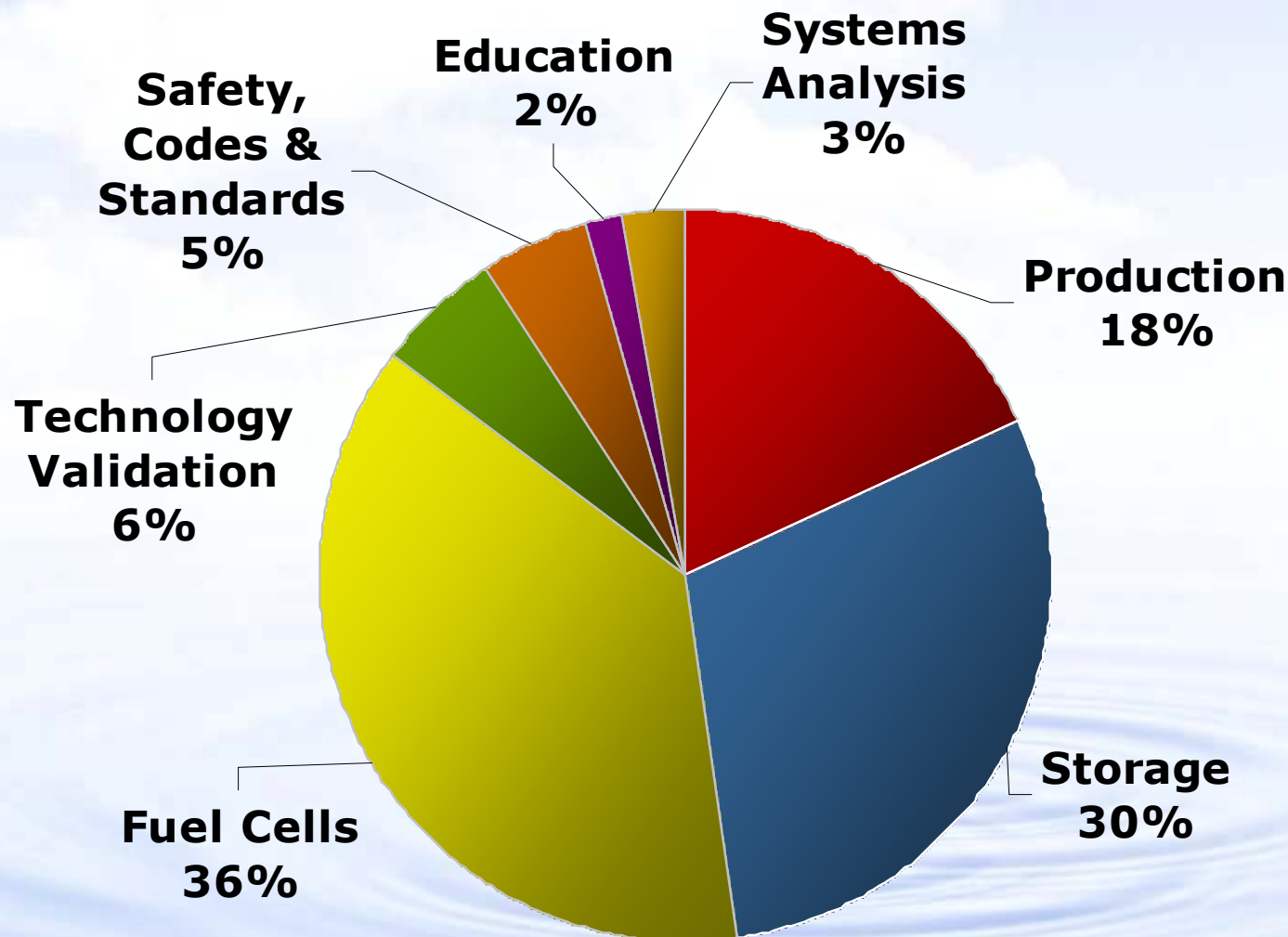


DOE FY 2009 Budget Request for Hydrogen Technologies

| Activity | Funding (\$ in thousands) | | | | | |
|---------------------------|---------------------------|---------------|---------------|-----------------|------------------|----------------|
| | EE/HFCIT | EE/VT | FE (coal) | NE (nuclear) | BES (science) | TOTAL |
| Hydrogen Production | | | 11,430 | 16,600 | 20,133 | 48,163 |
| Hydrogen Storage | 59,200 | | | | 20,134 | 79,333 |
| Fuel Cells | 79,300 | | | | 20,133 | 99,433 |
| Technology Validation | | 15,000 | | | | 15,000 |
| Safety, Codes & Standards | | 12,500 | | | | 12,500 |
| Education | | 4,000 | | | | 4,000 |
| Systems Analysis | 7,713 | | | | | 7,713 |
| TOTAL | 146,213 | 31,500 | 11,430 | 16,600 | 60,400 | 266,142 |



DOE FY 2009 Budget Request for Hydrogen Technologies





EERE FY2009 Budget Request

— Hydrogen remains a high EERE priority —

| ACTIVITY | FY2007 Approp (\$000) | FY2008 Approp (\$000) | FY2009 Request (\$000) |
|---|--------------------------|--------------------------|---------------------------|
| Biomass and Biorefinery Systems | 196,277 | 198,180 | 225,000 |
| Building Technologies | 102,983 | 108,999 | 123,765 |
| Federal Energy Management Program | 19,480 | 19,818 | 22,000 |
| Geothermal Technology | 5,000 | 19,818 | 30,000 |
| Hydrogen Technology | 189,511 | 211,062 | 146,213 |
| Hydropower | 0 | 9,909 | 3,000 |
| Industrial Technologies | 55,763 | 64,408 | 62,119 |
| Solar Energy | 157,028 | 168,453 | 156,120 |
| Vehicle Technologies | 183,580 | 213,043 | 221,086* |
| Weatherization & Intergovernmental Activities | 281,731 | 282,217 | 58,500 |
| Wind Energy | 48,659 | 49,545 | 52,500 |
| Facilities & Infrastructure | 107,035 | 76,176 | 13,982 |
| Program Support | 10,930 | 10,801 | 20,000 |
| Program Direction | 99,264 | 104,057 | 121,846 |
| Congressionally Directed Activities | 0 | 186,664 | 0 |
| Adjustments | 0 | -743 | -738 |
| TOTAL EERE | 1,457,241 | 1,722,407 | 1,255,393 |

* Includes \$31.5M for: Technology Validation; Safety, Codes & Standards; and Education



Challenges & Barriers

Technology Barriers

- **Hydrogen Cost**
(target: \$2 – \$3/gge)
- **Hydrogen Storage Capacity & Cost**
(targets: 2.7kWh/L, 3kWh/kg, and \$2/kWh)
- **Fuel Cell Cost and Durability**
(targets: \$30 per kW, 5000-hour durability)

Technologies
validated in
real-world
operation.

Economic & Institutional Barriers

- **Delivery Infrastructure**
- **Domestic Manufacturing and Supplier Base**
- **Safety, Codes & Standards Development**
- **Public Awareness & Acceptance**



EERE 2009 Hydrogen Key Activities

FY 2009 KEY ACTIVITIES/"PLANNED" MILESTONES:

STORAGE:

- Develop breakthrough storage materials and system designs that enable progress towards the 2010 system target of 6 percent hydrogen by weight. Demonstrate regeneration processes for chemical hydrogen storage and estimate their efficiency. Make Go/No-Go decision on sorbents/carbon-based materials.

FUEL CELLS:

- Accelerate fuel cell component research to reduce the high volume production cost of an automotive fuel cell system to \$60/kW in 2009 while increasing durability.
- Improve electrical efficiency of natural gas or propane fueled 5-250 kW stationary fuel cell systems to 36% at full power.
- Initiate small-scale, stationary solid-oxide fuel cell projects.



Funding Opportunities

H₂ Storage

- **H₂ Storage New Ideas:** Annual small solicitation to introduce new materials and concepts into portfolio. Planned \$3 – 6M over 2 – 5 years for 3 – 6 projects. Open: Pre-proposals due February 28.
- **H₂ Storage Engineering Center of Excellence (CoE):** To address onboard systems engineering. Planned \$35 – 40M over 5-6 years for one team. Planned issuance: March 2008.

Fuel Cells

- **2008 Solicitation/Lab Call:**
 - Request for Information released in November 2007 (www.gpoaccess.gov/fr/index.html)
 - Fuel Cell Pre-Solicitation Workshop was held in January 2008.
 - Ideas from the RFI and workshop will be taken into consideration for the solicitation/lab call to be released in April 2008

SBIR/ STTR

- **Annual Solicitations on a wide variety of topics**
- **2009 Solicitation subtopics expected in June 2008**



FY 2007 Accomplishments:

Steady Progress Toward Program Goals

R&D Advances

➤ **Production & Delivery**

- Completed installation and initial testing of project integrating wind power and hydrogen production
- Demonstrated small-scale solar-driven high-temp thermochemical water splitting (material cycled through 20 cycles with no apparent loss in activity)
- Developed improved reactor system for bio-derived liquids reforming (a 4x increase in reactor hydrogen productivity)
- Validated \$3/gge H₂ cost for natural gas reforming / hydrogen fueling system
- Feasible unit scoped and designed for centrifugal pipeline compression. In the natural gas pipeline infrastructure, centrifugal compressors are the most cost and energy efficient technology for this type of application.

➤ **Fuel Cells**

- Developed fuel cell membrane with nearly 5,000-hour durability
- Fuel Cell System cost @ \$94/kW via analysis (500,000 units/year)

➤ **Storage**

- Validated metal organic framework with highest material storage capacity to date worldwide (>7 wt%, 77 K)
- Achieved significant storage capacity (~3 wt%) in adsorbent material at room temperature, utilizing "bridged hydrogen spillover catalyst" (first room-temperature adsorbent).

Systems Analysis

- **Well-to-Wheels Analysis** completed
- Completed & validated test version of the "**Macro-System Model**," which provides full consistent pathway analysis of hydrogen cost and greenhouse gas emissions.



FY '07 Accomplishments

Steady Progress Toward Program Goals

Technology Validation

- Performance data provided from 77 vehicles, 14 stations
- Validated key performance metrics, including: vehicle range of 103 – 190 miles, 1600-hour durability, and 53 – 58% efficiency

Safety, Codes & Standards

- Completed *Technical Reference for H₂ Compatibility of Materials*
- Completed *Compendium of Permitting Tools* (under review)

Education

- Launched “Introduction to H₂ Safety for First Responders” education program
- Launched the “Increase Your H2IQ Public Information Program” (radio spots, podcasts, Hydrogen overview book)



Interagency Task Force

Progress and Future Plans

Established by the Energy Policy Act of 2005, Section 806:
Comprised of 20 key decision makers in 14 agencies and lead by DOE, the task force is working to facilitate interagency coordination of activities that will further the commercialization of hydrogen and fuel cell technologies.

Progress

- *Meetings held in August 2007 and December 2007*
- *Compiled information on all hydrogen and fuel cell activities at each participating agency, including:*
 - *Research and Development*
 - *Education and Outreach*
 - *Early Adoption (past, present, future)*

Future Plans

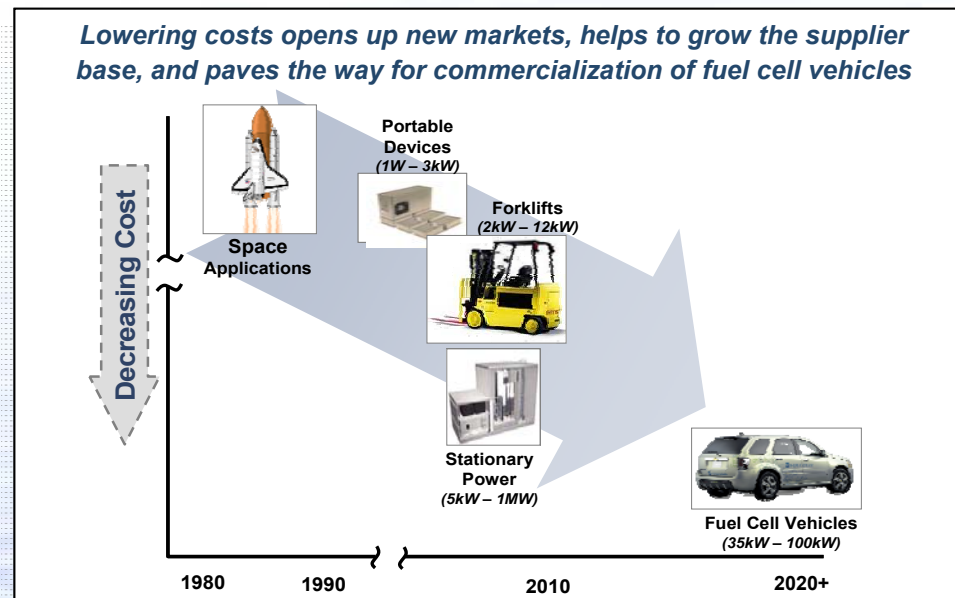
- *Next meeting to be held April 2008*
- *Focus will be on providing ITF members with tools, models and templates to assist with fuel cell deployments*
- *DOE Hydrogen Program Actions*
 - *Identify and provide financial mechanism templates (power purchase agreements, finance bundling, DOE Loan Guarantee)*
 - *Complete quantitative assessment of fuel cells (current and projected sales, effect of government intervention on manufacturing economies of scale, energy efficiency, emissions reductions)*
 - *Evaluate ways to increase number of fuel cell products on GSA schedule*
 - *Provide industry generated value proposition*



Market Transformation Activities

Accelerating commercialization of stationary, portable, and transportation fuel cells by facilitating federal deployments

- Technical and financial assistance to DoD for purchase/deployment of fuel cell forklifts
- Financial assistance to USPS for lease of up to 3 fuel cell vehicles
- Potential deployment of fuel cells at DOE data centers
- Deployment of backup-power fuel cells for the National Weather Service and the FAA
- Future deployments of backup-power fuel cells with telecommunications industry





Progress toward Key Technology Targets



Hydrogen Production

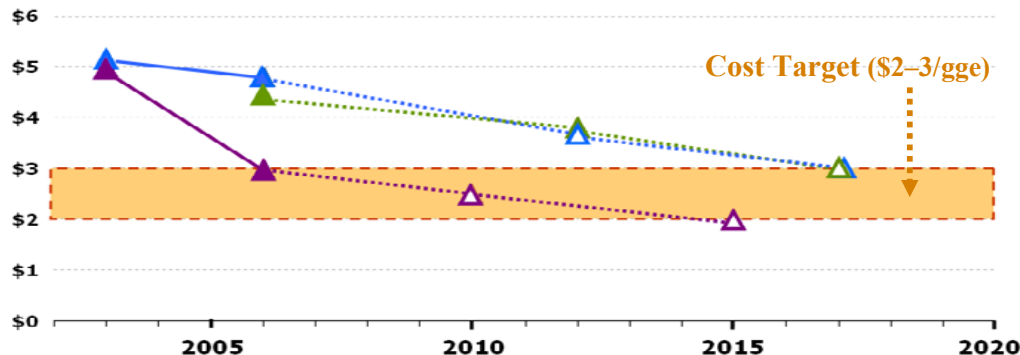
The Program has reduced the cost of producing hydrogen from multiple pathways.

Cost of Hydrogen (Delivered) — Status & Targets (in \$/gallon gasoline equivalent (gge), untaxed)

NEAR TERM: Distributed Production

→ Hydrogen is produced at station to enable low-cost delivery

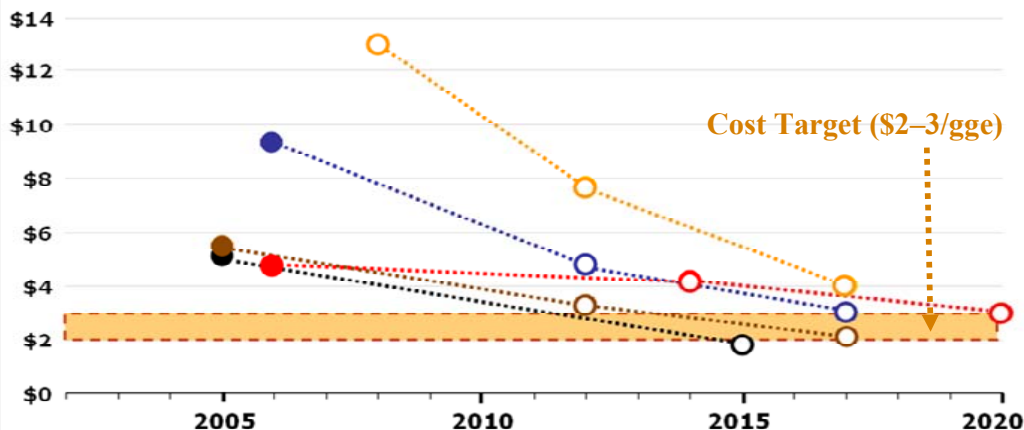
- ▲ Distributed Natural Gas
- ▲ Distributed Electrolysis
- ▲ Distributed Bio-Derived Renewable Liquids



LONGER TERM: Centralized Production

→ Large investment in delivery infrastructure needed

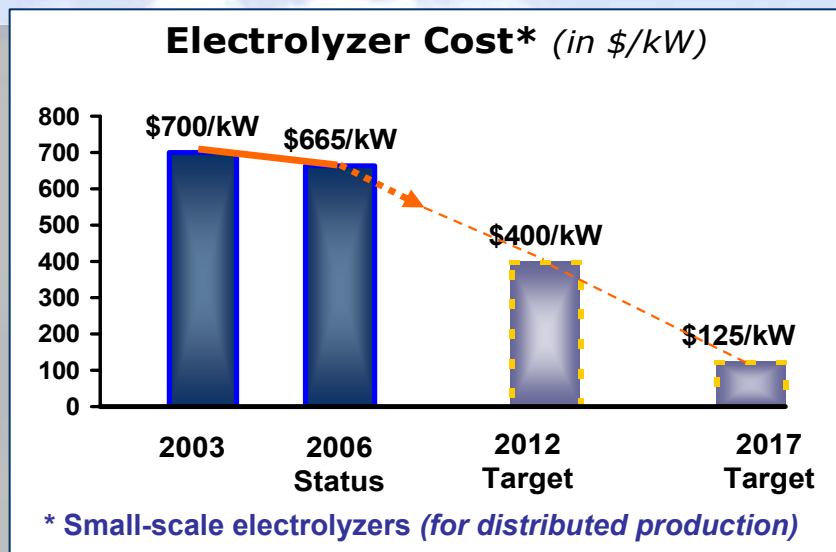
- Biomass Gasification
- Coal Gasification with Sequestration
- Solar High-Temperature Thermochemical Cycle
- Central Wind Electrolysis
- Nuclear





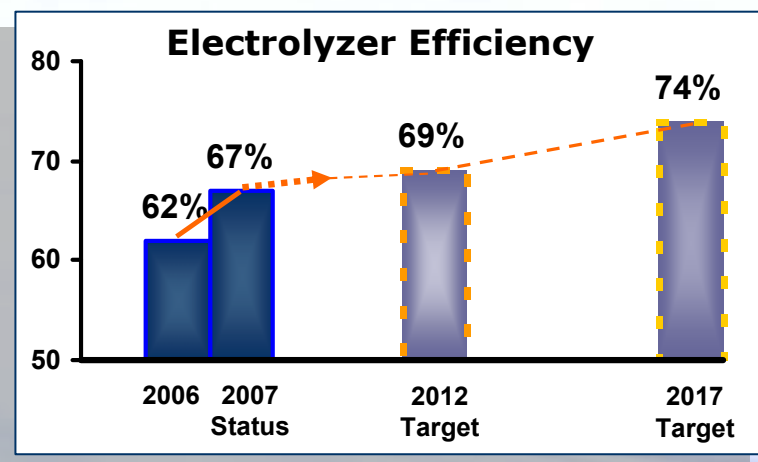
Hydrogen Production

The capital cost of electrolyzers is being reduced

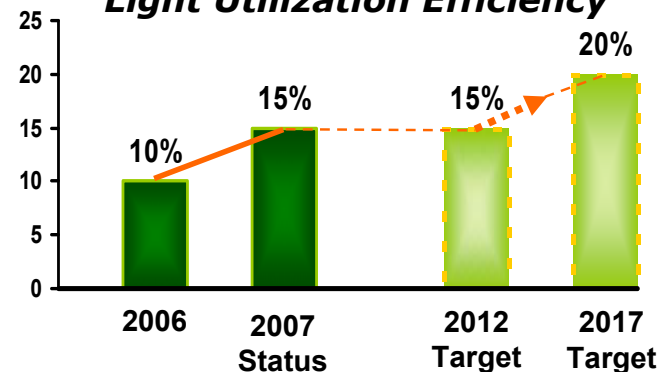


Progress is being made in biological production

The energy efficiency of electrolyzers is being improved



Biological Production: Light Utilization Efficiency

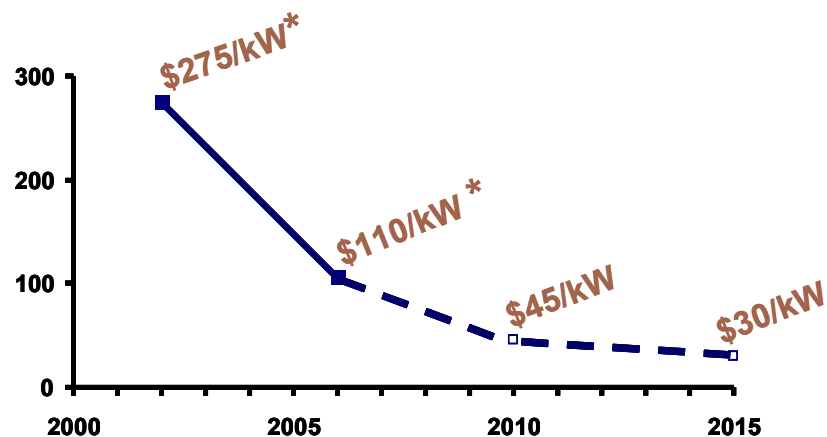




Fuel Cells for Transportation

Fuel Cell System Cost

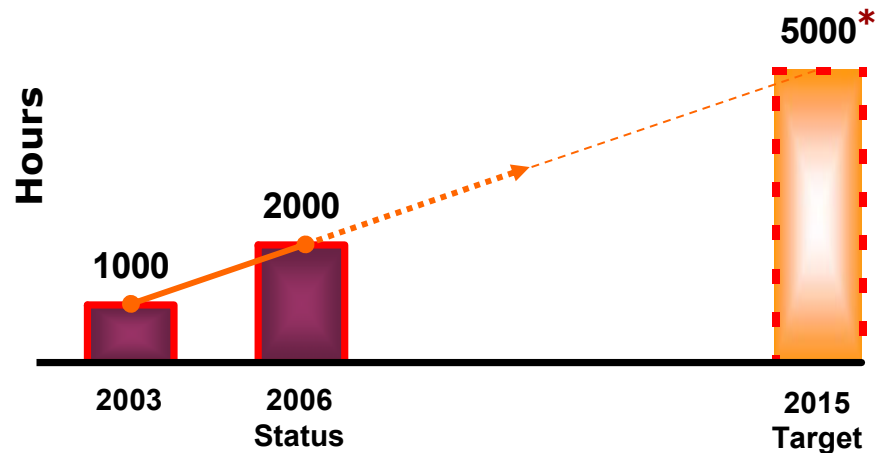
(80kW Direct H_2 automotive fuel cell)



* Projected to high-volume manufacturing of 500,000 units/year

Laboratory Stack Durability

(automotive fuel cell)



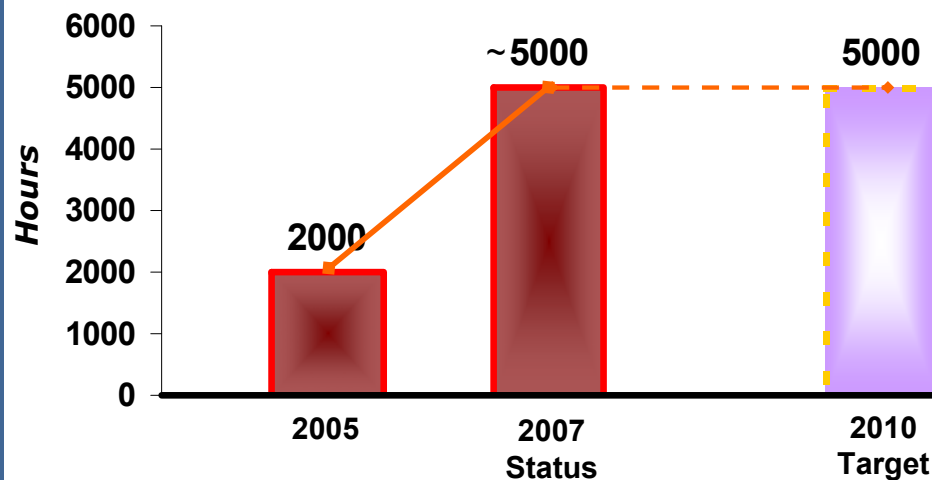
* 5000 hours corresponds to roughly 150,000 miles of driving



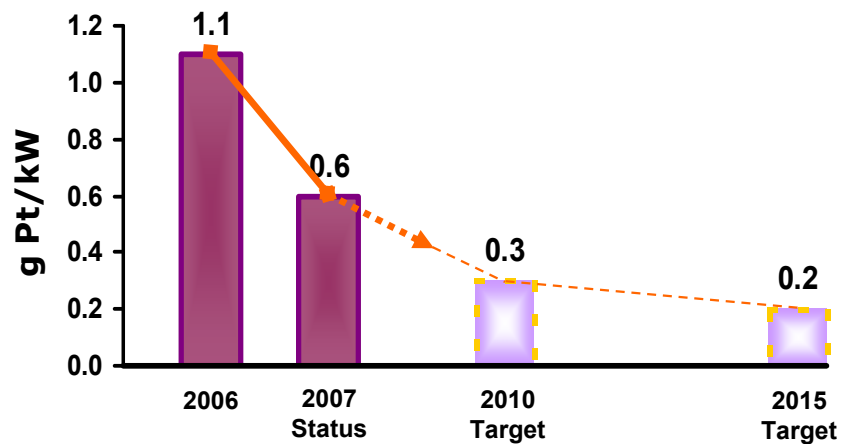
Fuel Cells for Transportation

Improvements in
membrane
durability

Membrane Durability — for Automotive Fuel Cells



Platinum Loading — for Automotive Fuel Cells



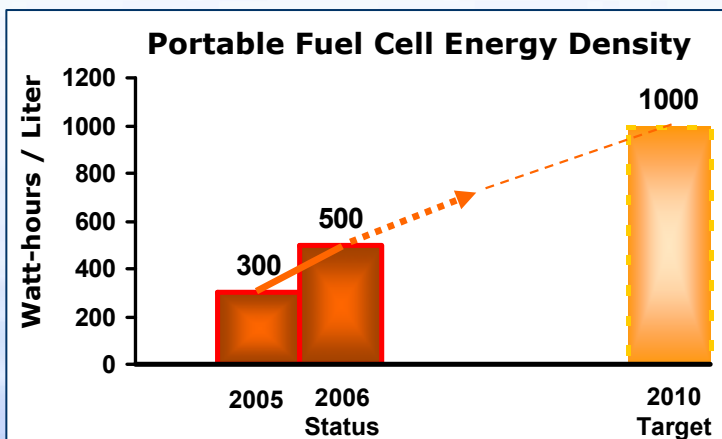
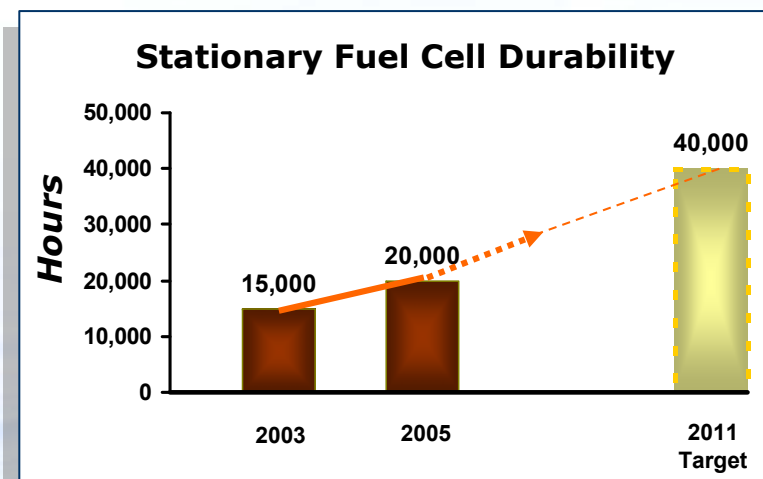
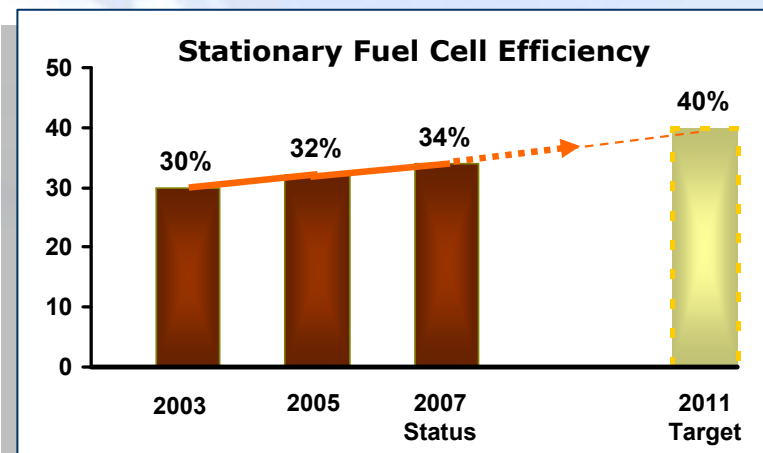
Reductions in
Platinum Loading



Fuel Cells for Stationary & Portable Power — Progress

FUEL CELLS for DISTRIBUTED STATIONARY POWER:

Improvements in efficiency and durability



FUEL CELLS for PORTABLE APPLICATIONS:

Improvements in energy density



2008 Annual Merit Review

Each year hydrogen and fuel cell projects funded by DOE's Hydrogen Program are evaluated during the Annual Merit Review and Peer Evaluation Meeting.

June 9 -13, 2008

Crystal Gateway Marriott Hotel
Arlington, Virginia

Hydrogen and fuel cell principal investigators representing the offices of **Energy Efficiency and Renewable Energy**, **Fossil Energy**, **Nuclear Energy**, and **Science** will present their project status and results in oral and poster presentations.

www.hydrogen.energy.gov



Recent Program Publications



Hydrogen, Fuel Cells & Infrastructure Technologies Program

Multi-Year Research, Development and Demonstration Plan

Planned program activities for 2003-2010



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Hydrogen Posture

An Integrated Research, Development and Demonstration Plan

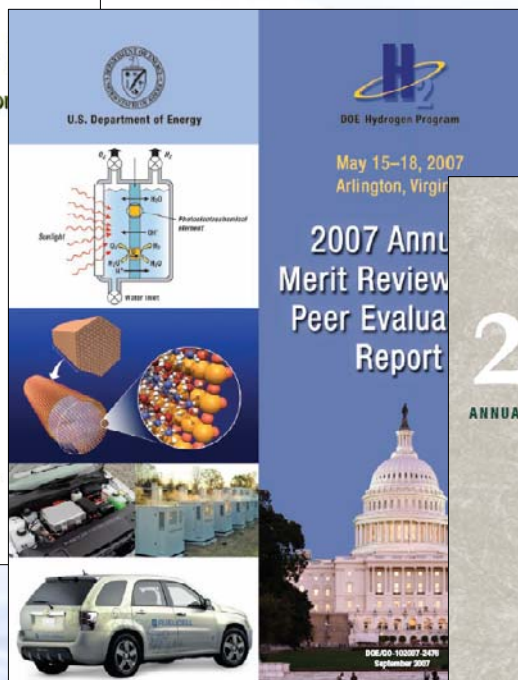
December 2006



United States Department of Energy



United States Department of Transportation



2007
ANNUAL PROGRESS REPORT

DOE
Hydrogen
Program



U.S. DEPARTMENT OF ENERGY

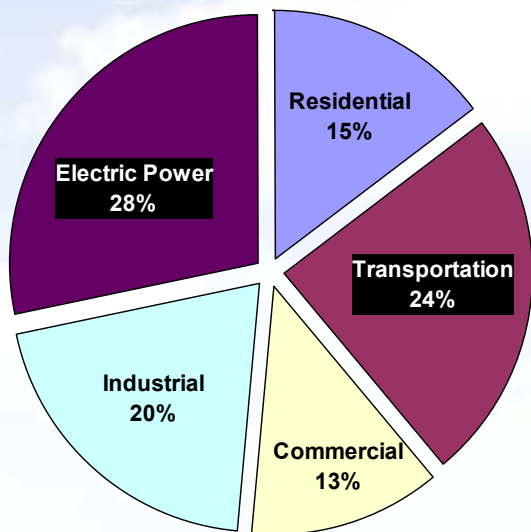
www.hydrogen.energy.gov/#key



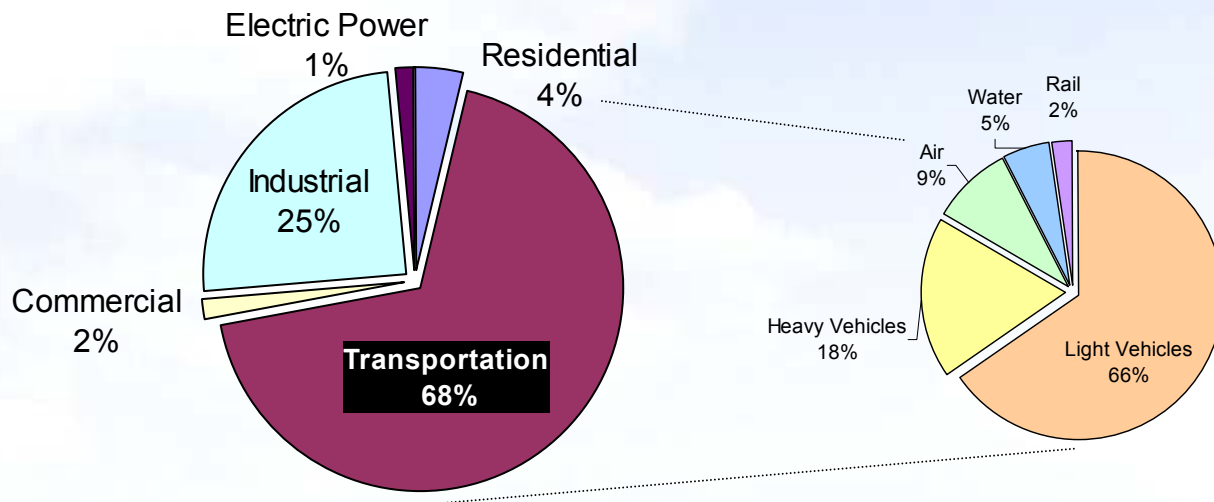
BACKUP SLIDES



Drivers: Climate Change & Oil Consumption



Domestic CO₂ Emissions by Sector (2006)



Domestic Oil Consumption (2006)

Hydrogen can address these issues:

- *Transportation: Use of Hydrogen in fuel cell vehicles can reduce oil use and carbon emissions in the transportation sector*
- *Power Generation: Hydrogen can enable clean, reliable energy for stationary and portable power applications*



CONTEXT: Policy (2003-2006)

HYDROGEN FUEL INITIATIVE (Jan. 2003):

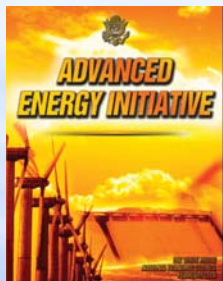


- \$1.2 billion over five years
- Establishes partnerships with private sector
- Develops hydrogen, fuel cell and infrastructure technologies
- Goal: to make fuel cell vehicles practical and cost-effective by 2020

EPACT 2005 (Public Law 109-58) TITLE VIII HYDROGEN:



- “Codifies” Hydrogen Fuel Initiative and reinforces DOE timeline
- By 2015: Industry commitment for fuel cell vehicles & infrastructure
- By 2020: Vehicles and hydrogen available for consumers
- Program authorized through 2020
- Federal Government as early adopter
- Federal Purchase Requirements for Fuel Cells (fleets & electric power)



ADVANCED ENERGY INITIATIVE (Feb. 2006):

- Accelerates research to reduce dependency on oil and natural gas
- 22% increase in funding for clean energy research
- Reinforces Hydrogen Fuel Initiative
- Accelerates R&D of near-term transportation options



CONTEXT: Policy (2007)



“20-in-10” INITIATIVE (Jan. 2007):

- Sets fuel standard at 35 billion gallons of renewable and alternative fuels by 2017, to displace 15% of annual gasoline use in 2017
- Expands scope of Renewable Fuel Standard (RFS) to “Alternative Fuel Standard”



Executive Order 13423 (Jan. 2007):

- Directs Federal agencies to implement sustainable practices for (1) energy efficiency and reductions in greenhouse gas emissions; (2) use of renewable energy; and (3) acquisition of green products and services.



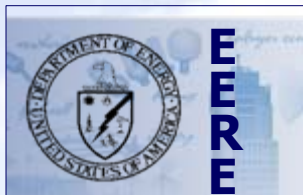
ENERGY INDEPENDENCE & SECURITY ACT (Dec. 2007):

- **H-Prize:** Establishes an award to advance the research, development, demonstration, and commercial application of H₂ energy technologies
- **Energy Storage Competitiveness Act of 2007:** Supports US global competitiveness in energy storage systems, including fuel cell technologies
- **Renewable Energy Innovation Manufacturing Partnership:** Makes awards available related to the manufacturing of renewable energy technologies, including fuel cells



Hydrogen Fuel Initiative

Key FY2009 Activities



DOE - EERE

--See slide 8--



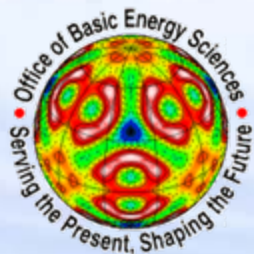
DOE - FOSSIL ENERGY

Validate improvements in small bench-scale prototype systems for multi-gas separation processes toward achieving hydrogen separation and purity targets.



DOE - NUCLEAR ENERGY

Operate integrated laboratory-scale Sulfur-Iodine thermochemical and high-temperature electrolysis experiments to gather data on operability and reaction rates. Design an integrated laboratory-scale experiment for the Hybrid Sulfur thermochemical cycle.



DOE - SCIENCE

Continue basic research on bio-inspired and solar hydrogen production, nanomaterials for hydrogen storage, and catalysis for fuel cells. Emphasize theory and modeling of the physical and chemical interactions of hydrogen with materials, nanostructured design, and novel synthesis.